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CUSHING.—Augite-syenite gneiss near Loon Lake, New York.

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Augite-syenite gneiss near Loon Lake, Ne
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BULLETIN OF THE GEOLOGICAL SOCIETY OF AMERICA
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AUGITE-SYENITE GNEISS NEAR LOON LAKE, NEW YORK

BY

H. P. CUSHING

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BY H. P. CUSHING

(Read before the Society December 30, 1898)

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INTRODUCTION

Field-work in a portion of the Adirondack region during the past two years has disclosed the rather widespread occurrence of rocks which resemble some phases of the anorthosites, and were classed with them until inspection of thin-sections showed their quite different nature. Similar rocks prove to be of frequent occurrence in the district, and to have an extent and importance not heretofore recognized. They also possess considerable intrinsic interest, so that some preliminary notice

of them would seem to be justified in advance of a thorough investigation of their field relations. These rocks are widely and quite typically exposed in the vicinity of Loon lake, in Franklin county, New York, and many of the exposures are easily accessible; hence their selection for descriptive purposes. The rocks are referred to the augite-syenites.

Megascopic Character

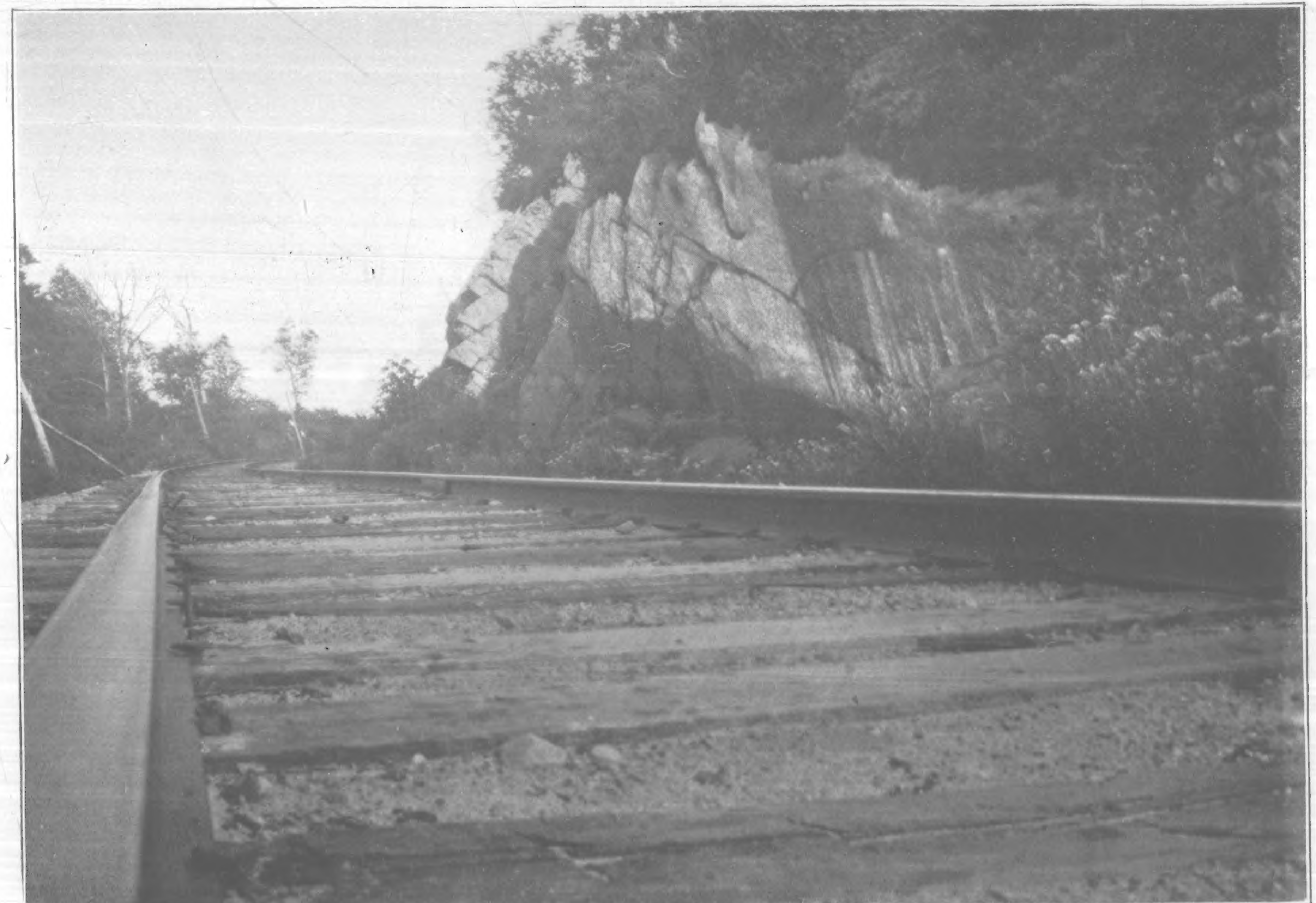
When fresh these rocks are of a grayish green color, which quickly changes to a more pronounced green on slight exposure. When longer exposed a further change to a yellowish or brownish green takes place, and then a passage into a rusty brown, which is the prevailing color of the exposures, except in recent cuts. The cause of these rapid color changes is not manifest, sections from specimens of the first three shades showing all the constituents to be perfectly fresh. Even the rusty brown rocks are often quite unaltered, though the hypersthene is commonly decomposed, suggesting staining from the oxidation of the ferrous oxide as a possible cause of the color here.

For the most part the rocks are of medium grain, though with much variation from place to place. They have been subjected to regional metamorphism in common with the other rocks of the district, and hence are rather evenly granular, though in most cases larger crystals are more or less abundant, suggesting cataclastic structure. Feldspar is much the most prominent mineral, constituting usually about 80 per cent of the rock. The uncrushed crystals are always less green than the granular feldspar. Pyroxene or hornblende and quartz make up the rest of the rock. Sometimes a little garnet and magnetite may be discerned. Biotite is locally present.

As a result of metamorphism, a rude foliation is commonly apparent, though with much variation from place to place, depending on the amount of ferromagnesian silicates present and on the degree of granulation. In other words, precisely the same range is shown that the gabbros exhibit, though very coarsely crystalline phases comparable to the coarse anorthosites have not been observed. In the more quartzose varieties the ferromagnesian silicates retreat with disappearance of the foliation, its place being taken by a rude linear structure due to the drawing out of the quartz into pencils.

Section near Loon Lake and its Interpretation

In the east end of Loon Lake mountain, south of and within 2 miles of the depot, the Adirondack and Saint Lawrence railroad has made three



RAILROAD CUT IN AUGITE-SYENITE, LOON LAKE, NEW YORK

The cut is half a mile south of Loon Lake depot. The dark portion is fresh and of green color; the lighter portion is somewhat weathered and is brown. Photographed by J F. Kemp August 2, 1898

rock cuts, which afford very interesting exposures.* In the first cut a fairly coarse augite-syenite is shown which has not been severely granulated, is practically non-foliated, and has a very evident cataclastic structure (plate 19).† The second cut shows quite similar material, though more crushed and with a better foliation. The third cut is quite extensive, and a generalized section of the exposures is given in the accompanying figure.

The augite-syenite constitutes the center and south end of the section. It is more thoroughly granulated and more gneissoid than in the preceding exposures. Separating the two syenite areas is a thickness of 12 feet of well banded gneisses. Above is a layer 2 feet thick of a white, granular rock composed of quartz and white pyroxene in the proportion of 1 to 2. This is followed by layers of granular, black pyroxene granulite and light colored quartzose rocks, the latter consisting essentially

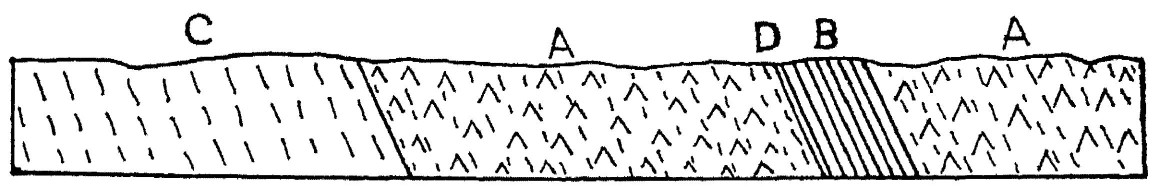


FIGURE 1.—*Section in Railroad Cut near Loon Lake, New York.*

A, augite-syenite. *B*, well banded quartzose gneisses. *C*, quartzose gneisses. *D*, biotitic sheared strip—strike north 10 degrees west. Dip of bedding and foliation 65 degrees to the west.

of quartz and potash feldspars, the quartz forming from 60 to 70 per cent of the rock. The structure and composition indicate a sedimentary origin for these included bands, and they are precisely like rocks which invariably accompany the crystalline limestones of the region, the white pyroxene being especially characteristic. At the lower contact with the syenite is a probable shear-plane, along which biotite is abundantly developed. This syenite is succeeded to the north by finely granular, red, granitic gneisses of doubtful origin, but also very similar to rocks which are of common occurrence associated with the limestones. The foliation planes of the syenite have the same dip and strike as the included gneisses.

There can be no question of the sedimentary origin of the gneisses included under "B" in the section (see plate 20). With that as a starting point, the uniform dip and strike in the exposure, together with the finely granular character of the syenite, give the impression that the whole forms a regularly bedded series; but when the syenite is compared with the rock in the other cuts it is seen to be unquestionably the

*These exposures were visited in company with Professor A. C. Gill in July, 1897, and with Professor J. F. Kemp in August, 1898, neither of whom objected to the interpretation here given.

†A photograph of this exposure is reproduced in plate 19 to indicate the color change due to weathering.

same, and that appears like a somewhat crushed intrusive rock. When it is recalled that the whole region has suffered profound dynamic metamorphism, producing a common foliation in the rocks irrespective of their origin; when it is further borne in mind that in the eastern half of the Adirondacks the rocks of the Grenville (crystalline limestone) series seldom occur in considerable belts, but rather in mere patches, and these patches are often wholly surrounded by undoubted igneous rocks, being found not infrequently inclosed in the anorthosites, and, further, that in the majority, if not in all cases, the bedding of the one and the foliation of the other are parallel, the seeming difficulty in the interpretation disappears; when, finally, the chemical nature of the rock is taken into consideration the case for its igneous origin seems made out.

It is not certain from the section whether the clastic rocks are in place and cut by large dikes of the intrusive, or whether they represent fragments caught up by the molten flood. Many examples of the latter might be cited from the eastern Adirondacks, and the great extent of the syenite in the vicinity of Loon lake with the scarcity of the Grenville series makes it the probable explanation here. Professor Kemp concurs in the view that these patches represent the remains of a once extended formation completely broken up by the great intrusions.

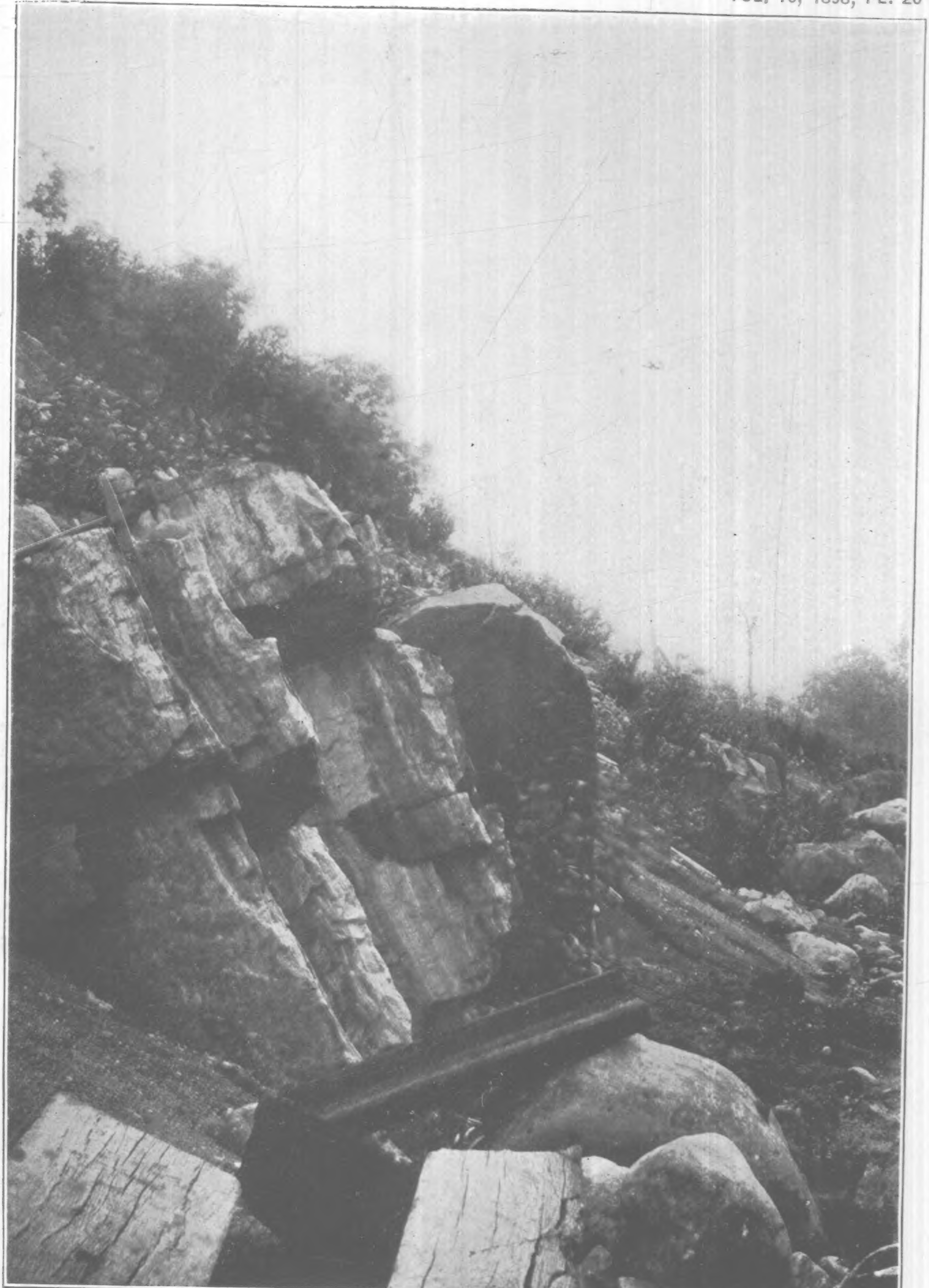
Microscopic Character and Mineral Constituents

The thin-section from the hand specimen chosen as typical and used for the chemical analysis shows the presence of the following minerals: Zircon, apatite, magnetite, garnet, hypersthene, augite, hornblende, oligoclase, microperthite, and quartz. Other slides from the vicinity of Loon lake show in addition biotite, titanite, allanite, and pyrite. The rock is essentially composed of microperthite, augite, and hypersthene, with quartz always present in varying and commonly slight amount.

Zircon and apatite are very sparingly present, are the only constituents with idiomorphic boundaries, and occur in the usual microscopic crystals as the earliest crystallization from the magma.

Magnetite is only in slight amount in irregular grains.

Allanite and titanite are found in only one of the slides and in only minute quantity. The titanite is of deep orange-brown color, like that in the pyroxene-granulites found associated with the magnetites of the Adirondacks. But two small fragments of allanite occur, so that its diagnosis is perhaps not beyond question, though the optical properties agree wholly with those of that mineral.



BANDED GNEISS INCLUDED IN AUGITE-SYENITE

The hammer is at the contact. Photographed by J. F. Kemp August 2, 1898

Garnet occurs only sporadically and is not idiomorphic, but appears in reaction-rim fashion between the magnetite and feldspar, sending out tongues into the latter mineral.

Of the pyroxenes, both hypersthene and augite are present, the latter usually predominating. Parallel growths of the two frequently occur, often of repeated fine lamellæ, the contact faces being as usual. Other growths appear also, and sometimes one mineral is found wholly included in the other, each appearing in that condition. Their boundaries are never idiomorphic, but always irregular and more or less rounded.

The hypersthene is quite typical, except that the prismatic cleavage is more pronounced than the pinacoidal. The augite recalls diallage in some respects, but the pinacoidal cleavage is absent or but poorly developed. The color is green, with a very slight pleochroism in the thicker slides, $\mathfrak{b}$ having a yellowish tinge. The ordinary color is very similar to the green of the hypersthene. Besides the prismatic cleavages there is a well developed parting parallel to the base. The extinction angle is between 45 and 50 degrees.

In the rock immediately under discussion hornblende is found in very slight quantity, though elsewhere present in considerable amount. Like the pyroxene, it appears in irregular grains, though sometimes there is an approximation to idiomorphic outlines. The absorption and pleochroism are very strong, $\mathfrak{a}$ being pale yellowish, $\mathfrak{b}$ deep brown, and $\mathfrak{c}$ dark green, with $\mathfrak{b} \geq \mathfrak{c} > \mathfrak{a}$. The $\mathfrak{b}$ color is very like the brown of the biotite, which also occurs sparsely in the more hornblendic rocks.

The feldspar is almost wholly microperthite. A few grains of plagioclase always appear and invariably extinguish nearly parallel to the trace of the albite twinning lamellæ. The greatest departure from parallelism in any of the slides was 7 degrees. In no other case does it reach 4 degrees. These fragments must therefore be referred to oligoclase. The chemical analysis shows that the plagioclase present must, as a whole, be considerably more acid than normal oligoclase and nearer to albite.

The feldspars are very fresh. They contain a small amount of cloudy, dust-like inclusions, and also include the zircon, apatite, titanite, and small augites, these latter being exceptional and idiomorphic. They also include small, idiomorphic or else rounded quartzes, as determined by Becke's method.

Orthoclase is only present as a constituent of the microperthite. There is no indication of zonal structure—that is, microperthite with oligoclase cores—as in the similar rock described by Smyth from Diana.*

*C. H. Smyth, Jr. This Bull., vol 6, pp. 271–274.

Quartz occurs only sparingly in this rock, though very quartzose phases appear elsewhere in the Loon Lake vicinity. It is mainly in rather large, elongated, cylindrical individuals. The elongation seems to be effected rather by solution and recrystallization than by crushing. The individuals are either entire or made up of but few fragments, and the fine granulation which must have been produced by the crushing process is nowhere in evidence. In the quartzose varieties the ferromagnesian silicates recede with disappearance of the foliation, its place being taken by a linear structure produced by the elongated quartzes.

Some quartz is also found as inclusions in the feldspar, sometimes rather numerously and with a tendency to micrographic growths. There is also a small amount of interstitial quartz and orthoclase, which seems secondary.

Structure of the Rocks

These rocks have a cataclastic structure. In the gneissoid rock, from the third cut the granulation is pretty complete, but even there occasional larger nuclei remain and show undulatory extinction. In the coarser rock, from the first cut many such large fragments are found, constituting more than half the rock. The Diana rock shows the structure even better. Precisely the same variations in degree of granulation are to be found that the anorthosites exhibit, except for the lack of the very coarse varieties in the syenite, such as make up a considerable part of the anorthosite, but this is regarded as an original difference. In addition to the cataclastic structure, the rock is nearly everywhere foliated.

Chemical Analyses

TABLE OF ANALYSES

These syenites are so variable in mineral content and their field relations to other rocks, which on the one hand are much more acid and on the other more basic, and into which they apparently grade, are yet so uncertain that a large amount of chemical work will be necessary in order to fully elucidate the problems suggested. Only a beginning has been made in this, which, however, suffices to show the character of the typical rock and to permit of a certain amount of discussion and comparison with other syenites.

	I.	II.	III.	IV.	V.	VI.	VII.
SiO_2	63.45	65.65	65.43	66.60	66.13	59.78	64.35
TiO_2	0.07	....	0.50	0.76	0.74	......	......
Al_2O_3	18.31	16.84	16.11	15.05	17.40	16.36	15.46
Fe_2O_3	0.42	4.01	1.15	1.07	2.19	3.08	7.50
FeO	3.56		2.85	4.42		3.72	
MnO	None.	......	0.23	Trace.	0.13	....	......
CaO	2.93	2.47	1.49	2.21	0.81	2.96	3.58
BaO	0.13	......	0.03	.....	......	......	.....
MgO	0.35	0.13	0.40	0.36	0.04	0.69	0.50
K_2O	5.15	5.04	5.97	5.42	5.60	5.01	3.45
Na_2O	5.06	5.27	5.00	4.03	5.28	5.39	3.28
P_2O_5	Trace.	....	0.13	.....	....	CO_2 0.75	......
Loss	0.30	0.30	0.78*	0.41	1.22	1.58	1.63
	99.73	99.71	100.18	100.33	99.54	99.96	99.84

Specific gravity of number I is 2.717 at 20° centigrade.

I. Augite-syenite (akerite), Loon lake, New York. Analysis by E. W. Morley.†

II. Augite-syenite (akerite) from Diana, New York. Description and analysis by C. H. Smyth, Jr., in this Bulletin, vol. vi, pp. 271–274.

III. Syenite, mount Ascutney, Vermont. Petrographical data by R. A. Daly, analysis by L. G. Eakins, in U. S. Geological Survey Bulletin no. 148, p. 68.

IV. Akerite, Gloucester, Massachusetts. Description and analysis by H. S. Washington, in Journal of Geology, vol. vi, p. 798.

V. Akerite, between Thinghoud and Fjelebua, Norway. Analysis by Mauzelius, description by Brögger, in Zeitschrift für Krystallographie, vol. xvi, p. 46, 1890.

VI. Syenite, Silver Cliff, Colorado. Description by Whitman Cross, analysis by L. G. Eakins, in 17th Annual Report, U. S. Geological Survey, part ii, p. 281.

VII. Banatite, Farsund, Norway. Description and analysis by Carl Fred. Kolderup, Bergens Museums Aarbog, 1896, p. 213.

DISCUSSION

The Loon Lake rock (column I) is composed of microperthite, augite, hypersthene, and quartz, with a little magnetite and oligoclase, and such small amounts of apatite and zircon that they in no way affect the totals. With this comparatively simple make-up it would seem an easy matter to calculate the composition of the rock. It soon appears, however, that the augite must be peculiar, and that a wholly satisfactory calculation can not be made until it has been analyzed. It must be either very rich in iron or alumina, or both, or else contain considerable alkali, but its optical characters are not those of any known alkaline pyroxene. Further, the available analyses of aluminous augites show that a high alumina percentage usually implies a large content of ferric iron, which is mani-

*Includes F, 0.08, Cl, 0.05; FeS_2, 0.07.

†The great obligations of the writer to Professor Morley for this analysis are gratefully acknowledged.

festly impossible here. The only way of interpreting the analysis that suggests itself to the writer is to assume that the augite is essentially a lime, ferrous-iron, alumina silicate, unusually high in the last named oxide.

Calculation of Analysis I

	Molecular ratio.	Magnetite.	Orthoclase.	Albite.	Anorthite.	Hypersthene.	Augite.	Quartz.
SiO_2	10575		3282	4896	318	174	745	1160
TiO_2	9	9						
Al_2O_3	1795		547	816	159		372	
Fe_2O_3	26	26						
FeO	494	35				87	372	
BaO	8				8			
CaO	523				151		372	
MgO	87					87		
K_2O	547		547					
Na_2O	816			816				
Per cent.		0.73	30.39	42.70	4.51	2.02	12.02	7.07

This result agrees quite well with that obtained by separation with heavy solutions, and can not be far from the actual composition of the rock. As it stands, the plagioclase is albite, Ab_{10} An_2, and the microperthite is approximately Or_3 Ab_5. The plagioclase is in all probability not quite so acid as this would imply, as the augite undoubtedly contains a little soda, which would displace some of the lime calculated in that mineral, and both lower the albite and raise the anorthite percentage. It is thought that this change is only slight, not materially affecting the calculation.

The agreement between analyses I and II is exceedingly close. The Diana rock is even more feldspathic than that from Loon lake, which accounts for the increased silica and diminished lime and magnesia of the former; but the rock at Loon lake is quite variable, and specimens could be selected which would tally almost exactly with the Diana analysis. No doubt also the converse is true.

Of the other available published analyses of American syenites, the two which stand nearest the Adirondack rock are quoted in columns III and IV of the table. Of the Mount Ascutney syenite, no published petrographic description is available.* A hand specimen and slide in the writer's possession show a green feldspathic rock very similar to that

* Dr Daly participated in the discussion following the reading of the paper before the Society, stating that the relations of the rocks of mount Ascutney had been carefully worked out and were in preparation for publication, and emphasizing the similarity of the Loon Lake rock.

from Loon lake except for its freedom from metamorphism. Hypersthene is lacking, and there is rather a predominance of hornblende over augite, which latter is colorless instead of green. Chemically it is closer to the rock from Diana than to that from Loon lake, but is lower in lime and magnesia than either. The agreement is, however, very close.

Likewise the syenite from Essex county, Massachusetts, just described anew by Mr. H. S. Washington, shows great similarity with the preceding.* It lacks hypersthene, and the augite is like that in the Mount Ascutney rock. The specimen analyzed is more acid than the Adirondack rock, with lower alumina, higher iron, and slightly lower alkalies, with the potash somewhat in excess of the soda. These differences are all slight, and of the essential identity of the rocks there can be no question. As stated by Washington for the Massachusetts rock, all belong to the variety of augite-syenite called "akerite" by Brögger and the "akerite type" by Rosenbusch—in other words, are quartzose augite-syenites. The analysis quoted by Washington of an akerite from Norway (column V) is appended, though, as stated by him, it is an acid representative of the group. Furthermore, it is unusually low in lime, much more so even than the Mount Ascutney rock. The analyses bring out clearly the considerable variation to which these rocks are subject. Not improbably they could all be duplicated in each locality.

All the rocks represented in the first five analyses are quartz-syenites and quite acid representatives of the syenite group, approaching the acidity of granites. Column VI gives an analysis of a more normal syenite, introduced merely to emphasize the departure of the others from the ordinary type.

Banatite is the name given by Brögger to rocks of the monzonite group (orthoclase-plagioclase rocks) which range between 62 and 67 per cent of silica. The analysis (column VII) will indicate the differences between them and these akerite-syenites, namely, the higher amount of lime and magnesia and lower alkalies. Rocks of the monzonite group are widely exposed in western Norway, a petrographical province which has many features in common with the Adirondacks, in close association with rocks of the gabbro group, anorthosites, norites, and so on. They have recently been exhaustively investigated by Kolderup,† and will be reverted to later.

Geologic Age

Quite fortunately the exposures in the railroad cuts near Loon lake furnish data for a rough determination of the age of the syenite. For

* Jour. Geology, vol. vi, pp. 796–798.
† Bergens Museums Aarbog, 1896, no. V.

a long period before the deposition of the Potsdam sandstone the Adirondack region was above sealevel, so that none but igneous rocks are found representing the time interval between the Potsdam and the only older sedimentary formation known in the district, the crystalline limestones and associated quartzites and gneisses. These latter are evidently the equivalents of the Grenville series of Canada. The syenites are younger than the Grenville rocks, for they cut or include them, as already noted. On the other hand, they are older than the youngest of the pre-Potsdam rocks, the diabases, for they are cut by them. In the first cut, 100 rods south of the depot at Loon lake, the syenite is traversed by a diabase dike 3 feet wide.

These diabases have not been metamorphosed, whereas the syenites have suffered change of such a character as to indicate that during the process they were deeply enough buried beneath deposits since eroded away to be in the zone of flow, so that a long time interval must lie between the two. In addition to these syenites, the gabbro rocks and certain granites are later than the Grenville rocks and much older than the diabases. The relationships of the gabbros, syenites, and granites to one another will be reverted to later. It should be stated that they are older than the Essex county, Massachusetts, rocks, which cut Lower Cambrian strata, according to Sears,* and are likely older than the Mount Ascutney syenite as well.

Adirondack Syenite Areas

Loon Lake

The Loon Lake syenite belt is quite extensive, having a length of nearly 20 miles and a breadth of 10, though of irregular shape. These figures are advanced with some hesitation on account of the difficulty of recognizing the rock in ordinary exposures, especially toward the periphery of the belt. It is only in recent cuts that fresh material is to be obtained. In ordinary outcrops a rusty, brown gneiss prevails, which may or may not show greenish, less weathered nodules when broken. The much elongated character of the quartz-augen often shows characteristically in these weathered rocks, and considerable dependence has been placed upon it as a criterion for their recognition; but this is only of avail in the more acid phases, whereas the fresh rocks are found to pass into varieties in which the ferromagnesian silicates become more prominent and quartz recedes. Weathered rocks of this type have a wide range. They are finer grained and better foliated than the type and,

*J. H. Sears: Bulletin Essex Institute, vol. XXII, 1890.

when weathered, are absolutely not to be distinguished from other rocks of apparently quite different relationships.

A variation is also shown in the opposite direction. Belts of very acid, red granitic gneisses consisting essentially of microperthite and quartz, with or without hornblende and augite, occur in the syenite-gneisses and *seem* to grade into them. For the most part they differ greatly in appearance from the usual granitic gneisses of the Adirondacks, being of coarse grain, with the quartz in the much elongated form in which it is found in the syenite-gneiss. These rocks are not so well shown in the Loon Lake belt as in others to be mentioned. The *seeming* gradation of the one into the other, the identity of the hornblende and augite, when they occur, in the two rocks, and the peculiar type of quartz are the reasons for assuming a near relationship to one another.

SALMON RIVER

A smaller belt of syenite-gneiss, some 6 miles long and 2 miles broad, runs from a point about 7 miles south of Malone down into Duane township. It is cut through by the Salmon river and the rocks well exposed, especially at Chasm falls. The fresh green gneisses are quite like those at Loon lake; but red gneisses make up a more considerable part of the exposures here, and in part the color is produced by weathering, instead of indicating a more acid rock. As a whole, hornblende is more prominent and pyroxenes less so in this belt, but no other differences appear and the identity of the rocks is beyond question. The only doubt is in regard to their areal extent, as they fade out into other rocks through puzzling intermediate phases.

DIANA

According to Smyth the Diana syenite belt is from 15 to 20 miles long and 2 to 4 broad, with very indefinite limits on all sides but the north.* To the south patches of it appear frequently in the midst of gneiss, into which it seems to blend, although the relation is obscure. Irruptive contacts with the limestones of the Grenville series are well shown, especially at Bonaparte lake. Professor Smyth writes me that he has found no other large area of this rock in the western and southern Adirondacks, though occasional small patches occur, with a wide range in distribution.†

MOUNT DEFIANCE

Professor Kemp has called my attention to the probable identity of

*C. H. Smyth, Jr.: This Bull., vol. vi, pp. 271–'74.

†An extended description of the Diana belt will be found in Professor Smyth's forthcoming report in the 17th Ann. Rep. State Geologist of New York.

the rock which constitutes mount Defiance, near Fort Ticonderoga, with these syenites, and inspection of his specimens and slides fully confirms the suggestion. Here also hornblende is more prominent than at Loon lake, but the characteristic augite is also conspicuous. Allanite occurs here likewise.*

BIG TUPPER LAKE

Rocks which are at least in part to be classed with these augite-syenites are excellently exposed along the shores of Big Tupper lake and extend widely to the north and east. They are closely involved with red granitic gneisses which equal them in extent and into which they grade. Together with these are other granites, of whose relations nothing can be said, as no contacts have been seen.

Relationship to the Anorthosites

The main interest attaching to the Tupper Lake syenite lies in the evidence it may be expected to furnish concerning the relations of the syenites to the anorthosites. A large area of anorthosite in southern Franklin county, in the heart of which the Saranac lakes lie, is surrounded by the Tupper Lake syenite on the south and west.

It may be said, in the first place, that the syenite cannot differ greatly in age from the anorthosite, having been intruded into the Grenville rocks and subsequently metamorphosed under the same conditions as to load, as shown by the character of the metamorphism. Again, their areal distribution indicates consanguinity. Further, the identity of many of the minerals in them and in the granitic gneisses as well combines to render it strongly probable that all have resulted from a common magma.

With such ideas in mind, a series of traverses were attempted from one to the other, which were unsatisfactory, owing to a lack of outcrops at the more crucial points. In some cases a blending of one rock into the other seems apparent in the field. The anorthosite becomes much crushed and very gneissoid near the peripheral parts of the mass, the blue labradorite-augen showing constant decrease in number and eventually disappearing entirely. When fresh these crushed rocks are much like the syenite in color and appearance, and weather into brown gneisses the exact counterparts of the weathered syenites, so that it is impossible to tell when the passage from one rock to the other is made, but the thin-sections do not wholly bear out the idea of such a blending. Anorthosites are found which contain both orthoclase and quartz, denoting an

*J. F. Kemp: Rep State Geol. N. Y. 1893, pt. i, p. 452.

approach toward the syenite, but no strictly intermediate varieties are yet forthcoming.

In other places the passage from one rock to the other is quite abrupt, with no sign of blending. Unfortunately no contacts have been noted, so that there is nothing to show which rock is the older. In two or three instances what seem to be small inclosures of unmistakable anorthosite in the syenite have been noted, but in each the latter is far from fresh, and there is some question of its identity.

The fact that areas of each are found wholly apart from any trace of the other is good evidence for the separate nature of the intrusions; nor is there any reason why differentiation should not have taken place for the most part before the intrusion of either, and yet that a further differentiation of local character should not also take place in parts of the anorthosite after reaching their present resting place and while yet uncooled.

Similar Petrographic Provinces

CANADA NORTH OF MONTREAL

The rocks of the Adirondacks are most naturally compared with those of Canada to the north, being separated from them by a comparatively narrow belt of Paleozoic rocks, beneath which the two are undoubtedly continuous. That rocks corresponding to these syenite-gneisses are present there is undoubted, though as yet no attempt has been made to differentiate them from the other gneisses of the region. This is not surprising, considering the difficulty of the task and the nature of the country to be explored.

Adams has described the Saint Jerome anorthosite as

> "Surrounded by a zone of rocks of varied character, many of which strongly resemble the anorthosite in appearance, but are quite different in composition," and which "consists chiefly of rocks which, in addition to augite and plagioclase, contain variable amounts of hornblende, orthoclase, and quartz, and which are thus intermediate in character between the gneiss and the anorthosite, some of the many varieties represented approaching more nearly to gneiss and others more nearly to anorthosite in character and composition." *

He expresses the opinion also that the zone is to be regarded as a peculiar border facies of the anorthosite. If this be the true explanation and the writer is correct in his correlation, the area furnishes evidence of the passage of one rock into the other of much more decisive character than any yet forthcoming in the Adirondacks.

* F. D. Adams: Geol. Surv. Can., Ann. Rep., vol. VIII, 1896, pt. J, p. 121

In the same report a number of pyroxenic gneisses are described as of doubtful origin, and some of them may belong here, though the majority of them are clearly referable to Adirondack types, which have nothing to do with the rocks under discussion.*

There are further described from many localities granitic gneisses with elongated quartzes, "leaf gneisses," which seem in part identical with those which appear in the Adirondacks associated with the syenite gneisses as apparent extreme phases of the magmatic differentiation.

LAKE SUPERIOR

Though the geological record preserved in the rocks of the Upper Lake region is a much more complicated and complete one than that to be read in the Adirondacks, still there is a close parallelism in the eruptive rocks of the two districts, as has frequently been urged by N. H. Winchell. Similar syenitic rocks also occur there with the same close relationship to the gabbros, so far as can be told from the descriptions, and have been described by Wadsworth and others.

NORWAY

Kolderup has recently described exhaustively a most interesting series of rocks which occur in the vicinity of Ekersund and Soggendal, in western Norway.† Unlike the other two Norwegian anorthosite areas, this one has not suffered regional metamorphism, so that the field relations are exceptionally clear. He shows that the original magma of the district has produced by differentiation anorthosite, norite and quartz-norite, and the various members of the monzonite group (orthoclase-plagioclase rocks), monzonite, banatite, adamellite, and granite. The order of appearance, according to Kolderup, was first anorthosite, then norite and monzonite, later adamellite and granite, and finally banatite, with no considerable interval of time between any but the first and second. Last of all and considerably later are dikes of diabase and augite granite. All these rocks agree closely in their mineralogy with the Adirondack eruptives.

Sequence of Eruptions in the Adirondacks

It is yet too early to attempt any complete discussion of the Adirondack igneous rocks, and, owing to the excessive regional metamorphism, it is an exceedingly difficult problem to work out the details of their

* Ibid., pp. 67–82

† Carl Fred. Kolderup. Das Labradorfels Gebiet bei Ekersund und Soggendal, Bergens Museums Aarbog, 1896.

history, but the similarity with the Norwegian rocks just mentioned is so great that it demands notice. The anorthosites are common to both regions. The norites and quartz-norites are also represented in the Adirondacks, partly as peripheral phases of the anorthosites which were undoubtedly produced by differentiation in place, and partly as somewhat later eruptions which cut the anorthosites and also the older gneisses, but which have not been noted cutting the syenite-gneisses. These norites grade into very basic ilmenite-norites and into quite pure masses of ilmenite in both regions.

The rocks of the monzonite group are represented in the Adirondacks by the syenitic and granitic gneisses here discussed. These rocks have certainly a range in silica percentage sufficient to include the banatites, adamellites and granites of Ekersund-Soggendal, and as far as can be judged from thin-sections the more basic monzonite end of the series is represented as well. In these rocks we meet the first considerable difference in the two districts. The Adirondack rocks, so far as chemically studied, run too low in iron, magnesia and lime, and too high in alkalies to be classed in the monzonite group (see analysis VII of the table), though the corresponding mineralogic difference is mainly to be seen in the character of the plagioclase, which is oligoclase in the latter and albite in the former. This likely points to some slight difference in the composition of the original magma, but the general resemblance is so close as to be very striking. Finally, in both regions the eruptive activity closed at a later period with the formation of diabase dikes accompanied by more acid rocks, syenite-porphyry in the Adirondacks and augite-granite in Norway.

A word of comparison with the Essex county, Massachusetts, petrographical province may not be amiss. The igneous rocks of the latter, according to Sears, consist of granites, syenites, and quartz-syenites, nepheline-syenites, essexites, diorites, and gabbros, all of which are cut by numerous dikes.* Leaving out the nepheline rocks, these are the same types as occur in the Adirondacks; but when the relative preponderance of the different varieties in the two provinces is taken into consideration it is clear that the original magma in the Adirondack region must have been considerably the more basic of the two, being lower in silica and the alkalies and higher in lime and magnesia; hence the prominence of gabbros in the one and of alkaline syenites in the other. Notwithstanding this considerable difference, some almost identical rock types appear in each as a result of differentiation. It is of interest to note that the two areas present almost precisely the same

* J. H. Sears in Bulletin Essex Institute, vol xxvii, 1895.

contrast to one another that is exhibited by the Christiana and Ekersund-Soggendal districts of Norway.*

Summary

1. A quartz-augite syenite gneiss near Loon lake is described as regards its field relations and megascopic and microscopic characters.

2. Chemical analysis shows it to be a member of the syenite group and an acid representative of the variety called akerite by Brogger

3. It is shown to be nearly related to the anorthosites in age, inasmuch as it is intrusive in the Grenville series, but much older than the pre-Potsdam diabases of the region.

4. Other Adirondack localities are briefly described, and the rock is shown to vary within quite wide limits, ranging from a granite to syenites more basic than the one analyzed.

5. The relations of the syenites to the anorthosites are discussed, showing a lack of decisive evidence, but indicating that syenites are in part a result of differentiation in the anorthosite magma after reaching its place of final cooling and in part are somewhat later in date.

6. Comparison is made with the similar petrographic provinces of Canada north of Montreal and of Ekersund, Norway, followed by a discussion of the order of eruption of the Adirondack eruptives, which is anorthosites, norites and diabasic norites, syenites, and granites, followed later by diabases and syenite porphyries.

7. A brief comparison with the Essex county, Massachusetts, province suggests that the original magmas in the two districts were quite different, yet another instance is added by them to the many already known of very similar rocks produced by the differentiation of quite dissimilar magmas.

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*See Kolderup, loc cit, pp 191-194